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DAIR SYSTEM RADAR TARGET RELATIONSHIPS

Allen C. Busch
Paul W. Bradbury

OCTOBER 1974

FINAL REPORT

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16. Abstract

To assist the FAA in evaluation of the DAIR system against other ARTS II candidates, measurement data were collected in 1969 on a prototype DAIR built by Whittaker Corporation, and an analysis was made of the relative accuracy of the digitized radar target symbol position versus the primary radar target. Radar track of one aircraft on radial courses was photographed as displayed in both primary and beacon radar modes, and also as processed through the DAIR system. Quantitative results were statistically analyzed to determine differences between primary radar position and displayed position, and to determine the distribution of the center of the displayed DAIR radar target position about the center of the primary radar target position. Results indicated that the DAIR system tended to display the DAIR center mark at a closer range and at a smaller azimuth angle than the center of the primary radar signal. The altitude of the aircraft did not appear to have any consistent effect on these measurements; however, the range of the aircraft did indicate a tendency to affect the measurements.

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INTRODUCTION

GENERAL

This report describes an investigation of the positional accuracy of aircraft radar targets displayed in an air traffic control (ATC) radar system. The technical effort was performed by the Federal Aviation Administration (FAA) at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey.

The equipment system which was the subject of this investigation was under development by the FAA in the process of modernizing the air traffic control system. The 1961 report of "Project Beacon," an engineering review of the national aviation system, recommended specific increases in the capabilities of secondary radar, which is beacon radar. A basic element was the military Mark X IFF (Identification Friend or Foe) beacon system, which was modified by the addition of coding capability called SIF (Selective Identification Feature). This new coding system was called ATCRBS (ATC Radar Beacon System).

As a result of the AIMS (ATCRBS-IFF-Mark XII-Systems) program of the joint services (FAA and military), terminal radar facilities operated by the Air Force Communications Service were provided with a new Mark X ATCRBS, the AN/TPX-42A, commonly called Direct Altitude Identity Readout (DAIR). This system interfaces operationally with radar air traffic control systems such as the airport surveillance radar, for example ASR-4, but provides separate and additional capabilities through digital techniques. The provision of tags, or data displays on the radar indicator, augments the air traffic controller's access to aircraft identification and flight status information, and minimizes coordination of information between controllers and pilots or other controllers.

Several versions of partly automated radar systems have been implemented in terminal air traffic control facilities of the joint services under the generic title of Automated Radar Terminal System (ARTS). ARTS I is a terminal radar tracking system installed at Atlanta, Georgia, which tracks primary and beacon targets and provides data blocks and tabular lists. ARTS IA, presently installed in the New York Common IFR Room, is a multiradar, multi-terminal version of ARTS I. ARTS II, for which DAIR was a candidate, is a beacon numeric readout system on an ASR-4 class of radar display, intended for use at low-density or medium-density airports. ARTS III is presently a beacon tracking automated system which can be modularly expanded to include radar tracking, multisensor, and all-digital displays.

DAIR is a beacon numeric readout system to be used at a low-density airport; whereas ARTS II is a modularly expandable, non-tracking, alphanumeric system.

Data for this study was collected in 1969 using a DAIR system built by Whittaker Corporation as a prototype AN/TPX-42; whereas the AN/TPX-42 systems currently in service are built by Airborne Instruments Laboratory.

Finally, radar inputs for this study of DAIR were derived from the NAFEC ASR-5 system, which is a research and development tool rather than a field operational radar.

PURPOSE

The purpose of this effort was to provide the relative accuracy of the digitized radar target displayed in the AN/TPX-42 (DAIR) radar display system, versus the primary radar target.

The technical requirements specified that the following would be accomplished:

1. Measure the distance between the center of the digitized target and the estimated center of the associated primary radar video target;

2. Measure the distance between the center of the digitized target and the most remote edge of the associated primary radar video target;

3. Record such measures through a range of altitudes (including the minimum altitude) and at maximum, intermediate, and close-in ranges; and

4. Provide statistical estimates showing the probability of various distances between the center of the digitized target and the estimated center of the associated primary radar video target (as in item 1 above); and between the center of the digitized target and the most remote edge of the associated radar video target (as in item 2 above).

BACKGROUND

In a meeting on March 25, 1969, FAA Air Traffic Service (ATS) coordinated with Systems Research and Development Service (SRDS) a request for a special measurement of the positional accuracy of the DAIR system digitized radar target.

This information was intended for use in evaluating the DAIR system against other ARTS II candidates and as a necessary input for the determination of air traffic control separation standards for application when DAIR equipment is in use.

The requested measurement of DAIR positional accuracy was conducted at NAFEC, Atlantic City, New Jersey, as part of an ongoing investigation of system error for air traffic control terminal area analog radar. Procedures and software for data collection and reduction already developed for the subprogram Terminal Area Radar System Error were applied with a minimum of adaptation and modification to the DAIR study. DAIR system processing of ASR-5 airport surveillance radar inputs was provided by equipment active in the ongoing project Operational and Technical Evaluation of DAIR.

On an expedited schedule, a measurement laboratory was established and calibrated in April, live-flight data collection runs were performed between May 2 and 9, extensive photo-data readout and subsequent data reduction were completed by August 8, and data analysis was performed by August 20, 1969.

Data analysis results were presented to SRDS, ATS, and NAFEC personnel concerned with the relevant subprograms on August 21 at FAA headquarters, Washington, and September 3 at NAFEC. Subsequent to this response to the immediate needs of the requesters, the project team was dissolved and its members diverted to other assignments.

SRDS has requested that a written report be filed to terminate the requirement, and for the convenience of others who may be interested, inasmuch as DAIR equipment is now in operation in the national air traffic control system.

DESCRIPTION OF THE DAIR SYSTEM

The tag name DAIR, an acronym for Direct Altitude and Identity Readout, was applied to the prototype AN/TPX-42 system that was developed by a joint FAA/DOD special working group to provide commonality of equipment compatible with individual civil and military terminal air traffic control facility requirements. All comments in this report regarding DAIR refer specifically to that configuration of DAIR equipment tested by the special working group in 1969.

The tested DAIR system consists of the FAA-type Air Traffic Control Beacon Interrogator (ATCBI-3), a beacon reply processor (Video Signal Processing Group), a display processor (Digital-to-Analog Converter), a modified radar display plan position indicator (PPI), and type A and B control boxes (see figures 1-4).

The DAIR system provides active readout of beacon numerics for each transponder-equipped aircraft, consisting of identity for Modes 1, 2, and 3A, and altitude information for Mode C interrogations. While numeric readout and display of flight status information is of particular interest in most DAIR applications, the sole interest of this study was the positional accuracy of aircraft radar target or target symbol display. For details of other features of the DAIR system, descriptive documents are listed in the references, in particular items 1, 2, 3, and 4.

The basic function of DAIR equipment is to provide digitally-derived synthetic display markers for the readout of beacon-furnished target information. The system capability for display of real-time primary radar information is preserved. Backup presentation of beacon bracket decode signals displayed in real time, superimposed on primary radar signals, is also provided.

FIGURE 1. DAIR PROCESSING EQUIPMENT

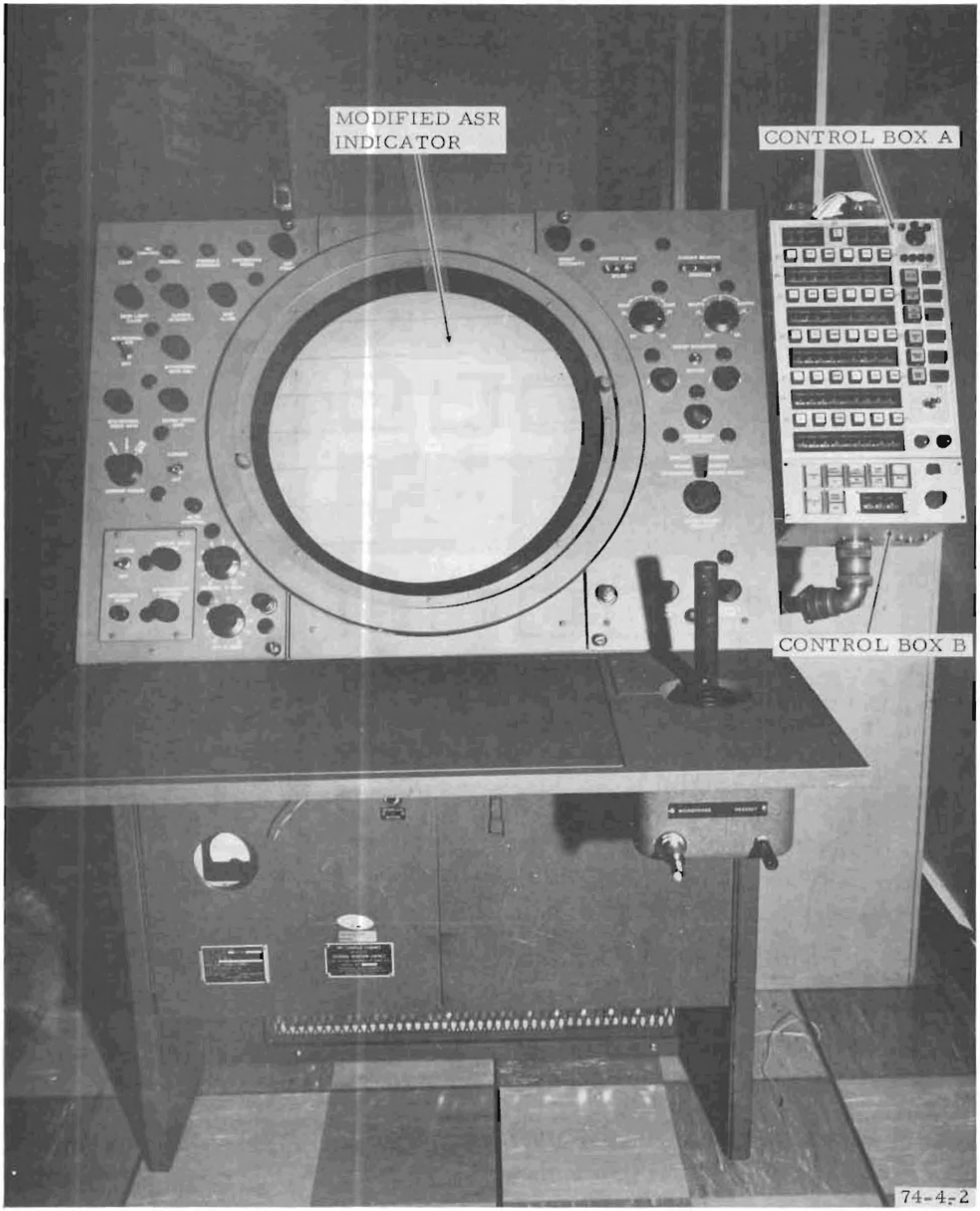

FIGURE 2. DAIR DISPLAY EQUIPMENT

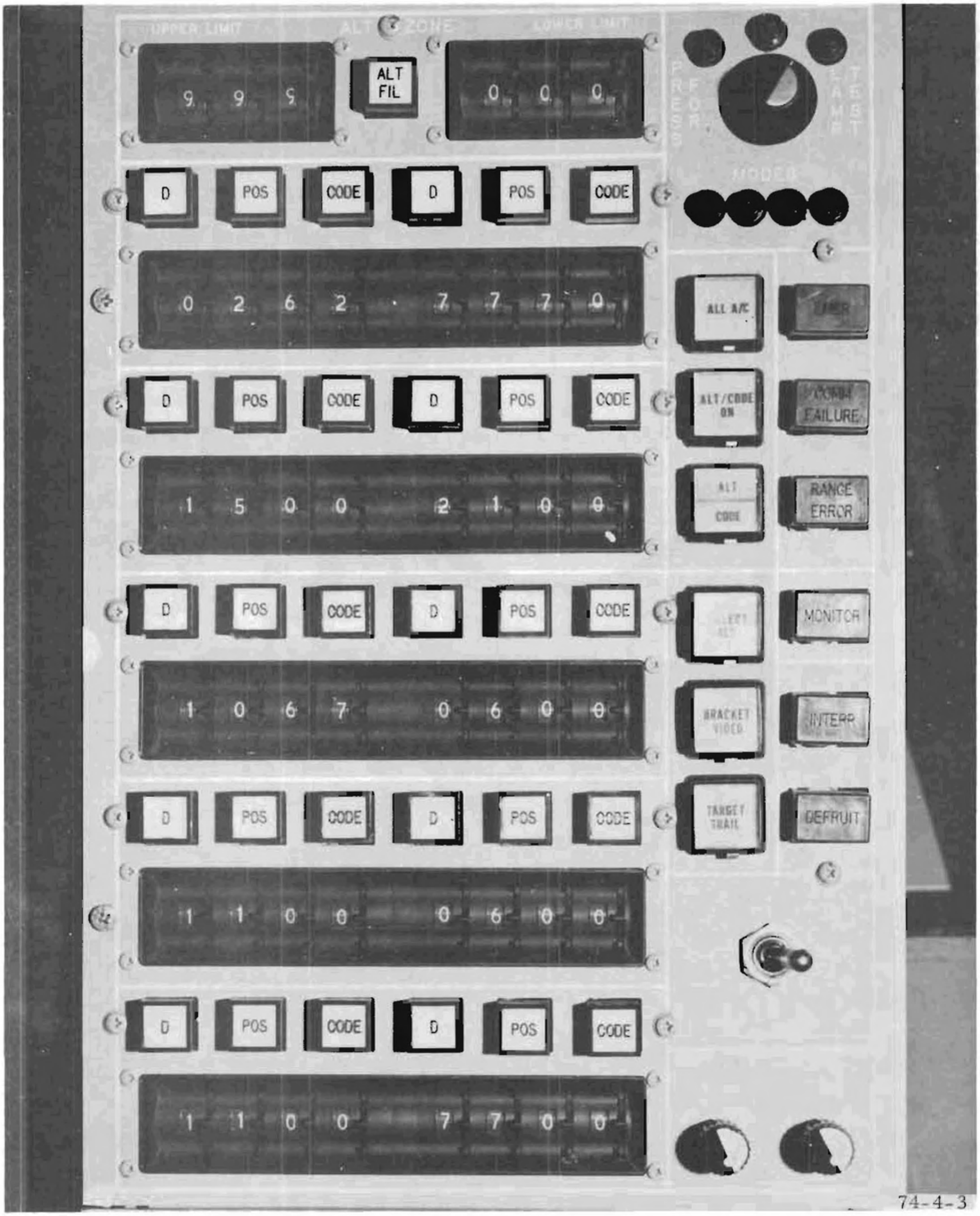

FIGURE 3. TYPE A CONTROL BOX

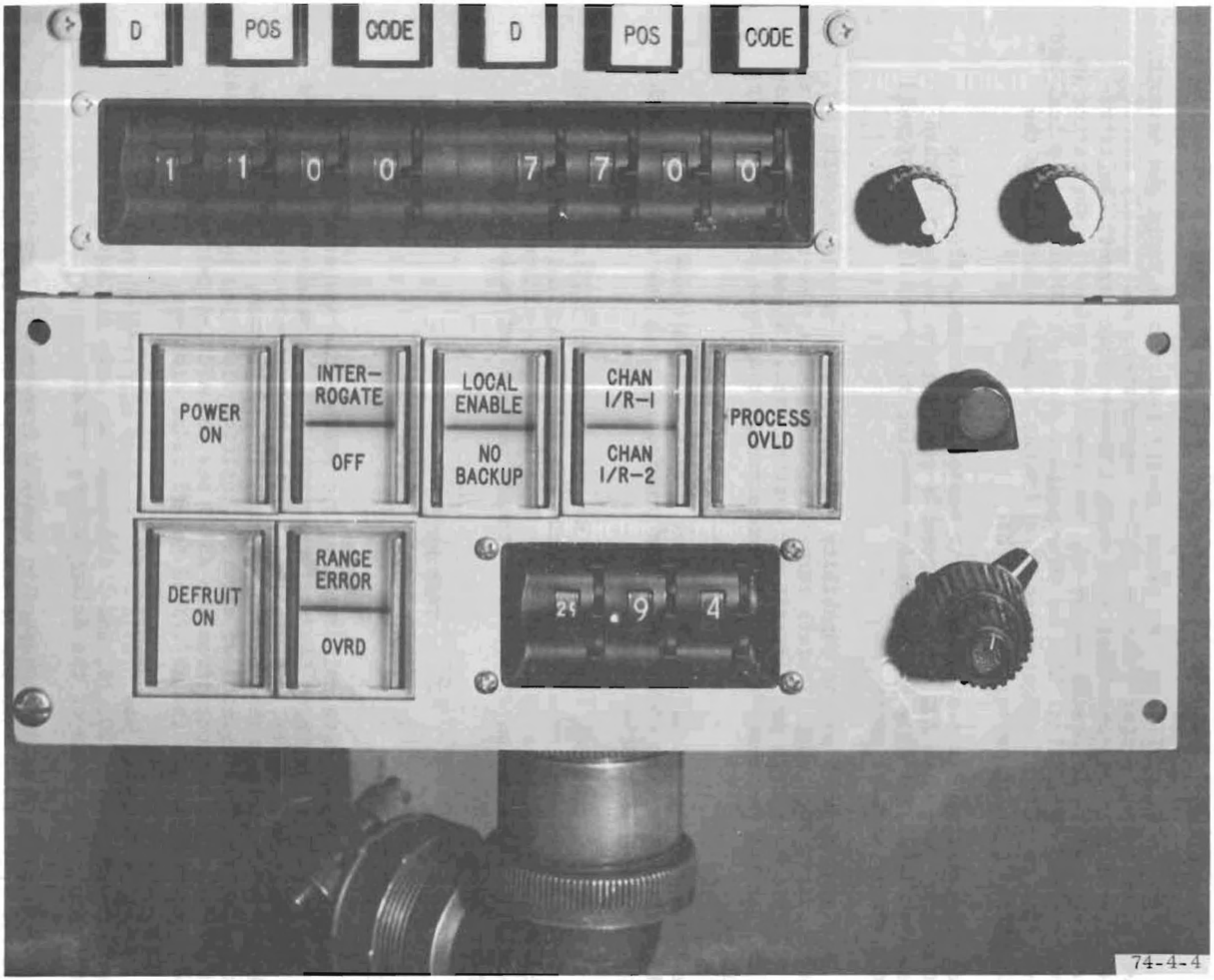

FIGURE 4. TYPE B CONTROL BOX

The DAIR system digitally derives target center position in range and azimuth, converts the target center position to X-Y coordinates, and closely associates the synthetic beacon marker with each primary radar target. Registration of the synthetic beacon marker and the real-time primary radar target is within one-eighth nautical mile up to a maximum range of 30 nautical miles, and within ± 0.4 percent of target range at all other ranges, according to the manufacturer's description (reference 2).

Where receiver/transmitter equipment is separated from data processing equipment by more than 500 feet, long-cable remoting can be accomplished by amplitude multiplexing techniques for remoting video and trigger signals over a single coaxial cable.

The DAIR system provides the capability for interfacing with a magnetic tape recorder, such that aircraft target reports are made to the recorder at the rate of one report per aircraft per antenna scan. These reports contain all the digital information which is concurrently displayed on the operating consoles.

A test signal synthetically generated at a selected range and azimuth for confirmation of system operation can be provided through use of the Azimuth Range Beacon Monitor unit (ARBM).

The DAIR system uses real-time display sweeps which are digitally generated and which are derived from the same data used for logging the coordinates of beacon targets for data processing. This feature is claimed to ensure accuracy in registration of synthetic target markers and real-time radar display.

TEST METHODOLOGY

METHOD OF APPROACH

The objective of the data collection was to measure the disparity between the center of the displayed DAIR target symbol and the relative position of the leading edge, center, and trailing edge of the primary radar target symbol. In the test method herein adopted, it was proposed to provide this information from photographs of aircraft position displayed by the AN/TPX/42 DAIR system. Radar inputs from the ASR-5 and the ATCBI-3 radar facility were processed through the AN/TPX-42 to PPI radar displays.

The target of interest was provided by one test aircraft on radial flight paths at altitudes of 20, 10, and 5 thousand feet mean sea level within a 60 nautical mile radius of the Atlantic City VORTAC.

Two PPI displays were photographed by cameras frame-mounted on the displays to record total scope coverage (figure 5). Both displays were set for a constant range of 60 nautical miles. However, display 1 was set up with

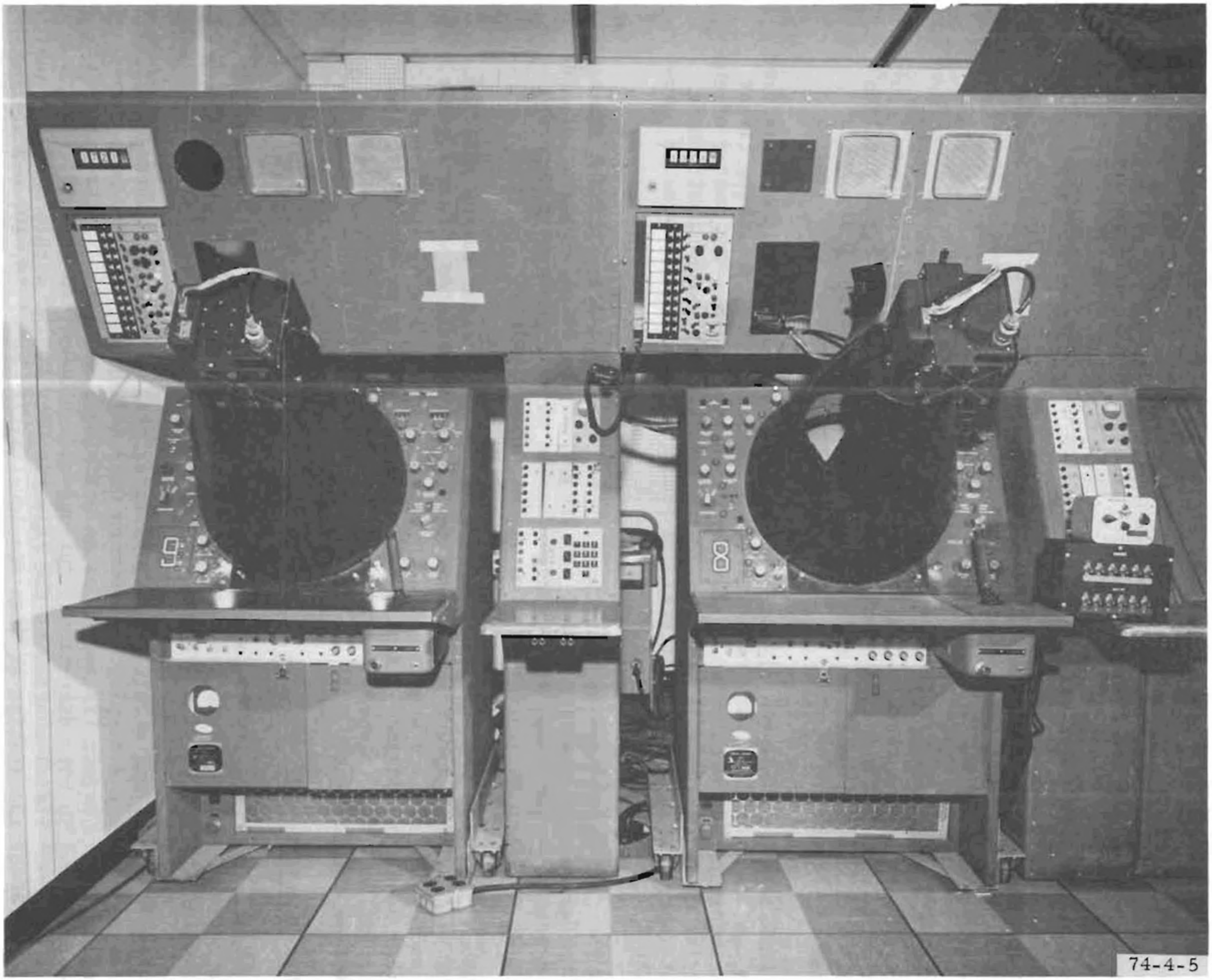

FIGURE 5. RADAR DISPLAYS WITH CAMERA INSTALLATIONS

radar main-bang centered, presenting 120 nautical miles on its 22-inch diameter; while display 2 was set up with radar main-bang off-centered to the edge of the scope so as to feature the radial being flown in a particular data run, and presenting only 60 nautical miles on its full diameter.

Both raw and beacon radar inputs from the ASR-5 were used on each display. Additionally, DAIR-processed beacon radar information was shown on both displays.

The cameras were automatically triggered to expose one frame of 35-mm film for each scan of the radar antenna; that is, one frame every 4 seconds. For time correlation of all data, each display was equipped with a presentation of clock time which would be recorded on film to the nearest 0.1 second of camera trigger.

The DAIR target symbol was displayed as an "X," and was slightly off-centered from the associated primary radar target by a fixed amount to ensure target discrimination for both modes of display on the data film. The center of the X indicated the aircraft's position. The aircraft radar target position in slant range and azimuth (rho-theta) was read from data film to punched cards in the Telereadex facility.

Thus the difference between the primary radar target position and the center of the DAIR target position symbol was treated as the total system error, and was measured at the point of service. That is to say, the camera recorded what the air traffic controller sees on his radar display.

It should be noted that component errors of the total radar target position error were neither sought nor identified. Errors associated with the radar processing and display system, or with the DAIR processing equipment are neither investigated independently nor reported. It was an assumption that the additive sum of component errors was not what was called for in the technical requirement.

AIRCRAFT ENVIRONMENT

To maximize productivity of data collection periods, targets of opportunity were not used. Instead, a test aircraft was flown on prescribed maneuvers to provide the target of interest.

The test aircraft was selected for good radar profile to ensure successful target detection and display. A Grumman G159 Gulfstream was used most frequently, and a Convair T29 served as an occasional substitute. The aircraft flew data runs in both directions, inbound and outbound, on the 090°, 180°, 270°, and 360° radial courses of the Atlantic City VORTAC within a 60 nautical mile radius of the station at mean sea level altitudes of 20, 10, and 5 thousand feet. Data collection was interrupted within the 5-mile range, while the aircraft overflew the radar antenna.

A data run was defined as test aircraft track on a single radial of the VORTAC between 60 nautical mile range and 5 nautical mile range, either inbound or outbound, and at one of the specified altitudes.

Elements of the NAFEC range instrumentation environment were used to integrate flight testing and to ensure reliable space-position-time data. Real-time code and control pulses, as well as communications circuits, were also provided.

LABORATORY ENVIRONMENT

For the ground environment, a measurement laboratory was established by installing two PPI radar displays in the DAIR equipment room to interface with DAIR processing equipment which was already in operation for a DAIR evaluation program.

This co-location and link-up ensured appropriate and proper installation, calibration, shakedown, and daily technical maintenance for the equipment system which was the subject of this study.

Synchronization of all data records was accomplished by interface with NAFEC Range Control Central Facility. For time correlation, each radar display was equipped with a presentation of clock time which would be recorded on the film to the nearest 0.1 second of camera trigger.

To establish alignment and scale for each frame of data film, eight synthetic targets were generated by the DAIR equipment (ARBM). These were displayed on the photographed radar indicators as fixed, stationary targets at 10 and 40 nautical mile ranges on the 090°, 180°, 270°, and 360° radials of the VORTAC.

The 22-inch diameter face of the radar indicator on each display was masked out with a paper overlay which was slotted to reveal to the camera lens the radial of the VORTAC that was being flown in that particular data run. This enabled the air traffic control specialist conducting the test runs to set radar display brightness, contrast, and focus controls at best levels for photographing that portion of the display, and at the same time to delete from all other quadrants irrelevant random targets, and radar blooming or strobing caused by electronic interference or noise. Elimination of such distractions from the data film was of some benefit subsequently in the Telereadex process for readout of measurement data from the film.

The position of the DAIR-processed target on the radar indicators was offset by the technical staff at our request, such that the DAIR target symbol was always closer to the radar main-bang, or radar antenna site location on the display, than was the unprocessed primary radar target, and the controlled bias was of a fixed amount throughout the tests. This was to provide discrimination between the various modes of radar target display, and eliminate ambiguity for the photo-data reader.

The target of interest for the data film reader was the target position symbol "X" generated and displayed by the DAIR equipment. It was located by position information which the DAIR system derived digitally from input radar information in rho-theta. The DAIR system determined the center of the beacon radar video slash, converted rho-theta to X-Y coordinates, and closely associated the digitized position with a primary radar target. No other targets on the data film appeared as DAIR "X's," with exception of the eight permanent echo (PE) synthetic targets.

Additionally, the test aircraft squawked a special beacon code assigned for exclusive project use, and this code was the only "selected" beacon code activated during data runs on the 10-channel beacon code selectors installed at the two radar displays. This ensured that the test aircraft would be the only dynamic target displayed as a beacon target, either unprocessed (beacon slash) or processed (DAIR "X").

DATA METHODS

DATA FILM CODING

The experimental design consisted of four basic test conditions with their various treatment levels: radar displays (2), flight altitudes (3), radial courses (4), and aircraft headings (2) on each course. This design yields 48 combinations of test conditions; and 24 live flight tests yielded 48 data runs for analysis.

A data run is defined as test aircraft radar track photographically recorded (in one of three radar modes - primary, secondary, or DAIR processed), on a single radial of the VORTAC between 60 and 5 nautical miles range, in one direction - inbound or outbound, and at one of the specified altitudes (20, 10, or 5 thousand feet).

The data film collected for this study of the DAIR system consists of 16 rolls of 35-mm film, each approximately 1,200 frames. Each frame corresponds to a 4-second scan by the ASR radar antenna. The sample divides into two sets of simultaneous photographs, one for a radar-centered display (display 1) and the other for an off-centered radar display (display 2).

Although the sample is large, automated data processing methods were to be used to alleviate the tedious workloads presented by sample size and multivariate test design. Opportunities were exploited to codify the data run numbering so as to identify the combination of variable test conditions applied in each run. The hundreds digit indicates the display number (and distinguishes reruns), the tens digit indicates flight altitude, and the units digits indicates both the heading and the radial of the course of flight.

Run Number Scheme:

100 series - Display 1, first attempt
200 series - Display 2, first attempt
300 series - Display 1, first rerun
400 series - Display 2, first rerun
500 series - Display 1, second rerun
600 series - Display 2, second rerun

Tens digit - 1 for flight altitude 10,000
2 for flight altitude 20,000
5 for flight altitude 5,000

For visual flight rule (VFR) compliance, as appropriate to aircraft heading, 9,500 and 10,500 were flown in lieu of flight altitude 10,000.

Units digits: Radial and heading (inbound/outbound)
1 - Radial 360°, heading 360°
2 - Radial 360°, heading 180°
3 - Radial 180°, heading 360°
4 - Radial 180°, heading 180°
5 - Radial 090°, heading 090°
6 - Radial 090°, heading 270°
7 - Radial 270°, heading 270°
8 - Radial 270°, heading 090°

Thus the three digits separately flagged display, altitude, and flight radial by treatment level (figure 6). In addition, the project computer programmer applied these codified flags as triggers for data sorting in the automatic data processing.

DATA FILM READOUT

Readout of the X-Y coordinate intersections of radar-displayed aircraft targets from data film of the displays was performed by the data preparation unit using Telereadex 29E film readers. This equipment includes a film projector adjustable in two planar directions, rotatable, and with optional lens selection and focus control (figure 7). Thus, data film projected on a reading surface similar to an engineering drawing board can be rotated and enlarged to enhance the reading procedure. The reading table is equipped with a horizontal and a vertical crosshair which the operator aligns on each specified object point to read in increments of 1/326 inch. In automatic mode, the X-Y coordinate readings, which are presented in windows on an associated data console for visual reference by the operator, can be punched into an IBM card by use of an action key. In semiautomatic mode, the coordinate readings are manually transferred to coding sheets for subsequent data cardpunch.

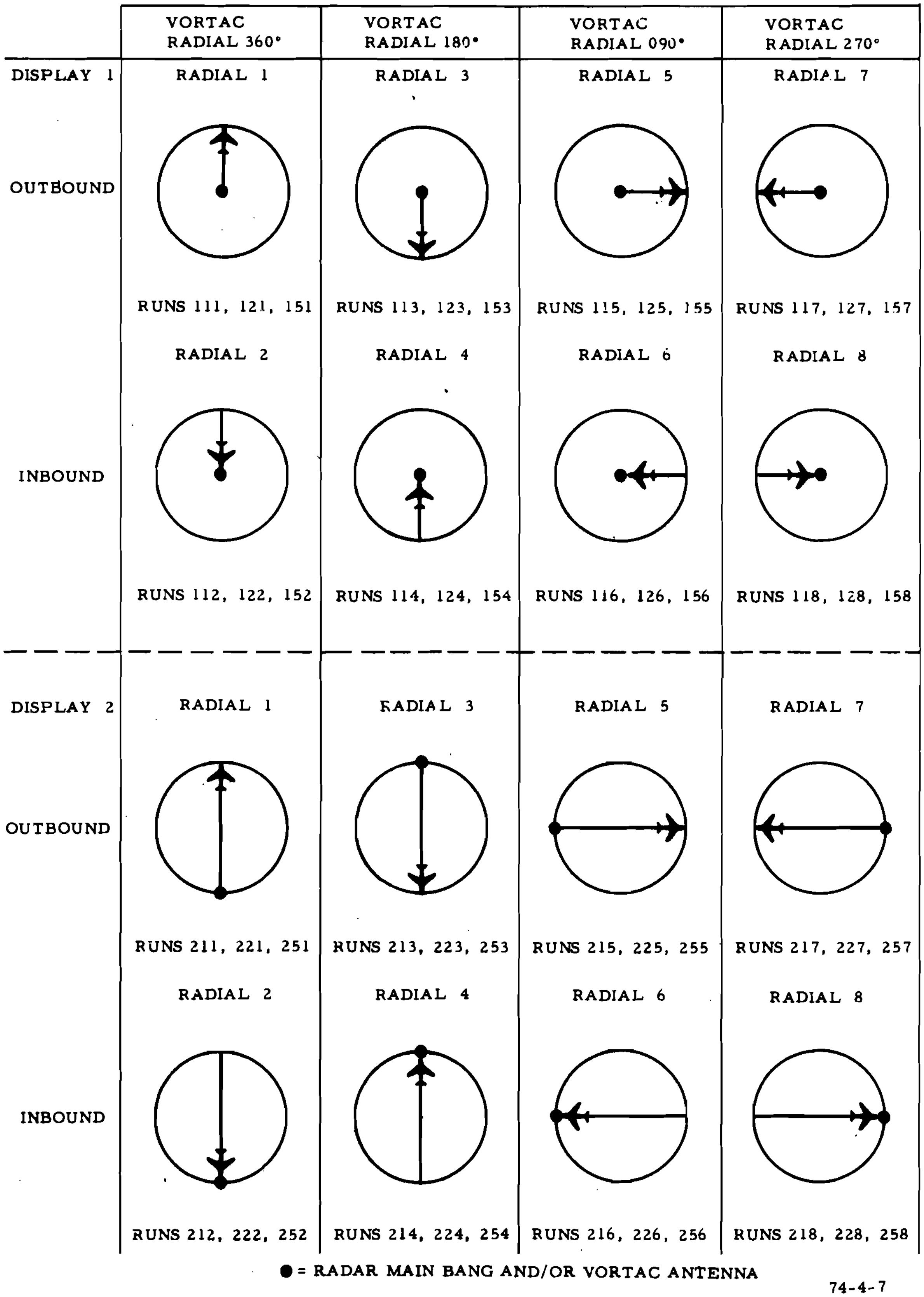

FIGURE 6. FLIGHT RADIAL NUMBERING SCHEME

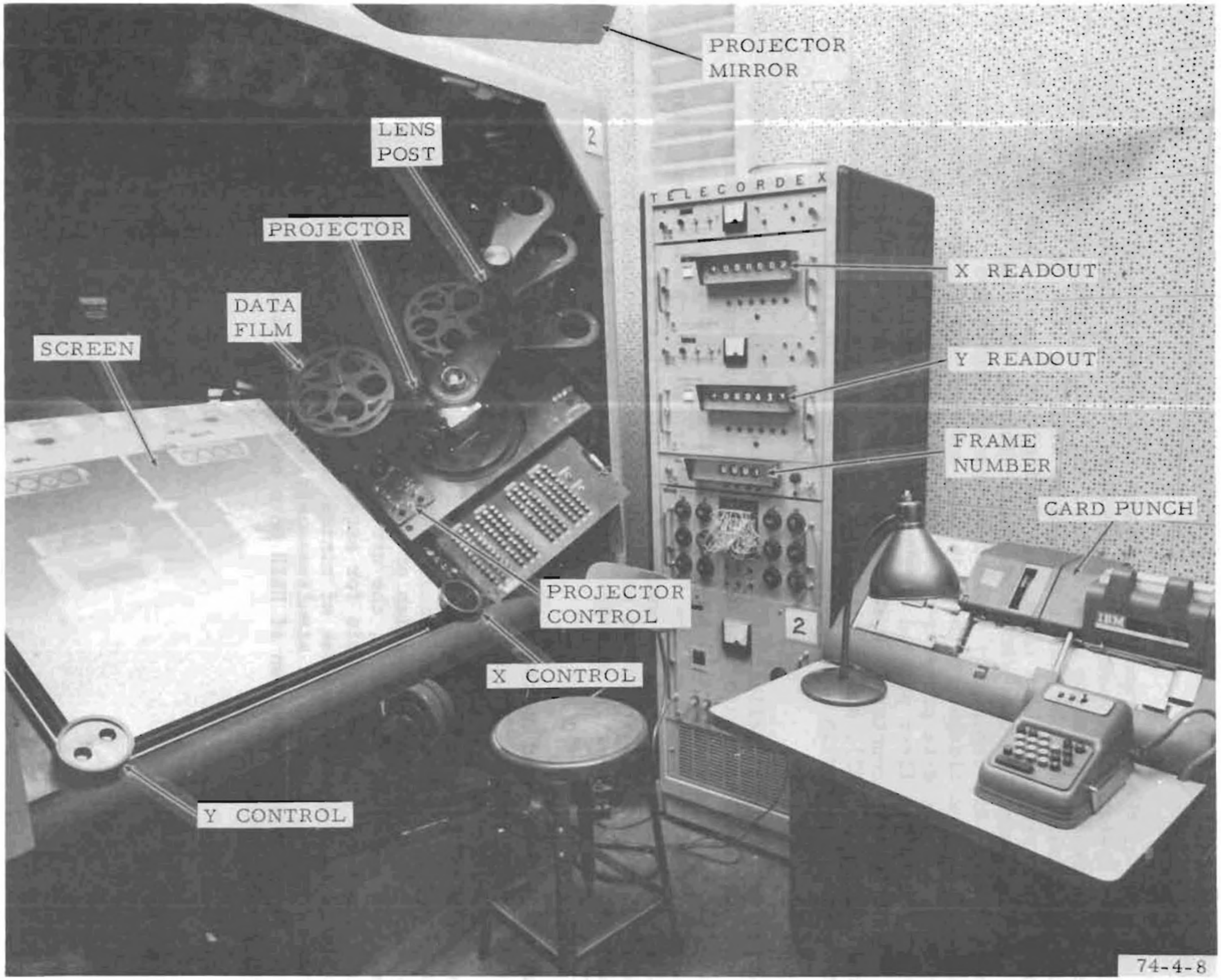

FIGURE 7. NAFEC TELEREADEX FILM READER EQUIPMENT

The operator of the film reader machine was instructed to read the center of the DAIR system target symbol, which was an "X." In addition, the operator was to read the leading edge, center, and trailing edge of the primary radar target slash for the target associated with the DAIR "X." For purposes of this project, these terms were defined differently than they are in air traffic controller use. For air traffic control "leading edge" and "trailing edge" are frequently spplied to beacon targets and refer respectively to the edge closest to the main bang and the edge farthest from the main bang. In the data procedures for this project, leading edge is the part of the target first painted in the clockwise rotation of the radar antenna, and therefore, the counterclockwise terminus of the target depiction on the cathode ray tube (CRT), and the trailing edge, conversely, is the final edge of the target painted in each clockwise scan, hence the clockwise edge of the target symbol.

To establish scale and alignment for each frame of film, the operator used the synthetic DAIR-generated targets which were positioned as static PE's at the 10 and 40 nautical mile ranges on the VORTAC radial for the data run. The operator zeroed out the Telereadex crosshairs on one PE and then realigned the crosshairs on the second PE to obtain the X-Y measurement between PE's. Telereadex realignment on permanent echoes was requested for each frame of data film that was read in order to ensure consistency of alignment and scale for all data.

Data editing was based on the procedures and methods of the air traffic controller in field practice. For example, ghost radar targets more than a minimum distance from true target position do not confuse the air traffic controller as to aircraft position, but are treated solely as one of the possible types of radar interference or noise. Split digital targets frequently bracket the last series of good hits projected, and are usually of minimum duration; therefore, the air traffic controller tends to reject them and not use them as a basis for establishing aircraft separation. Data on these system aberrations was of minimal interest in this particular series of tests, inasmuch as simultaneously both an engineering evaluation and an operational evaluation of DAIR were being conducted by others under another subprogram.

ANALYSIS

GENERAL

Since coincident registration of DAIR target symbology with normal radar would derogate measurements sought, at least by the photographic procedures which were used, the radar displays and DAIR equipment were aligned in such a way that the DAIR target symbol was displaced, in range only, from the primary radar target center. That is, the DAIR symbol center was offset such that it was always closer to the radar antenna (or display center) than was the primary radar target, and by a fixed amount.

To compensate for this offset, each data run was analyzed with a linear regression analysis. That is, the following equation was solved: $\overline{y}_1=\theta+b_1x_1$, where $\overline{y}_1$ is the range of the center of the primary target (at time 1), x_1 is the range of the center of the DAIR target (at time 1), b_1 is the linear estimate of the slope of the function (in this case, approximately one), and θ is the estimate of any bias or residual offset not accounted for by the electronic offset. Thus the value of θ was then used to compute the "true" value of the DAIR symbol with no offset relative to the primary target.

From the basic data (photographs) a series of measurements and calculations were made. All measurements/calculations were made relative to radar center. The following is a list of those calculations.

1. The slant range of the DAIR symbol center minus the slant range of the calculated center of the primary target (in nautical miles).

2. The azimuth of the DAIR symbol center (in degrees) minus the azimuth of the calculated center of the primary target.

3. The straight-line distance between the DAIR symbol center and the calculated center of the primary target (in nautical miles).

4. The slant range of the DAIR symbol center minus the slant range of the radar trailing edge of the primary target (in nautical miles).

5. The azimuth of the DAIR symbol center (in degrees) minus the azimuth of the radar trailing edge of the primary target.

6. The straight-line distance between the DAIR symbol center and the radar trailing edge of the primary target (in nautical miles).

7. The slant range of the DAIR symbol center minus the slant range of the radar leading edge of the primary target (in nautical miles).

8. The azimuth of the DAIR symbol center minus the azimuth of the radar leading edge of the primary target (in degrees).

9. The straight-line distance between the DAIR symbol center and the radar leading edge of the primary target (in nautical miles).

10. The straight-line distance between the calculated center of the primary radar target and the measured center of the primary radar target (in nautical miles).

RESULTS OF ANALYSIS

Table 1 presents the summary of the 10 calculations for each display. The data are presented according to the altitude the aircraft were flying. The data indicate that there were no significant differences as a function of altitude.

Table 2 presents the summary of the 10 calculations with the data arrayed according to the slant range from the radar center. The data blocks are (minimum range) approximately 3.0 to 18.5 nautical miles; 18.5 to 29.5 nautical miles; and 29.5 to approximately 57.0 nautical miles (maximum range). The minimum and maximum ranges for any one flight varied due to a large variety of conditions.

The data blocking indicates a tendency for the calculations for range differences (Nos. 1, 4, and 7) to increase as the aircraft got further from the antenna. The straight-line difference between the various segments of the primary target and the DAIR symbol center (variables Nos. 3, 6, and 9) got larger as the range from antenna to aircraft increased.

To examine more closely the effect of range on several of the variables, additional analyses were made. Figures 8, 9, and 10 show the effect of range on azimuth size of the primary target (in degrees), on a scan-by-scan basis. Figure 8 is for a flight at 20,000 feet (data run No. 123), figure 9 is for a flight at 10,000 feet (data run No. 113), and figure 10 is for a flight at 5,000 feet (data run No. 153). Data from table 1 (algebraic sum of variables Nos. 5 and 8) indicate that the average azimuth size of the primary target was 1.725°; however, the data in figures 8, 9, and 10 indicate that the relationship of the azimuth size of the primary target is not a linear function of range.

These data clearly demonstrate that, within the range of the measurements made, the primary target increases in angular size as it approaches the radar antenna (both as a function of range and altitude). This phenomenon is undoubtedly due to the design of the radar with its cosecant-squared antenna gain characteristic. Figure 11 presents the data from figure 9 (run No. 113) in a linear form. This figure indicates that the actual size of the primary target (on a PPI-type display only) increases at a slow rate as the target gets further from the radar antenna. On this one run, the primary target was approximately .96 nautical mile wide at a range of 10 nautical miles, and increased to about 1.22 nautical miles wide (width being from radar leading edge to the trailing edge as displayed on the PPI) at a range of 45 nautical miles.

TABLE 1. SUMMARY CALCULATIONS BY ALTITUDE

		VARIABLES									
DISPLAY 1		1	2	3	4	5	6	7	8	9	10
Altitude No. 1 (20,000)	$\overline{m}$	-.048	-.221	.191	-.035	-1.273	.562	-.070	.827	.409	.058
N = 748	s	.100	.463	.115	.115	.629	.217	.101	.530	.162	.037
Altitude No. 2 (10,000)	$\overline{m}$	-.132	-.270	.287	-.117	- .426	.618	-.155	.724	.438	.050
N = 1022	s	.117	.538	.148	.121	.747	.205	.118	.541	.175	.032
Altitude No. 3 (5,000)	$\overline{m}$	-.026	-.213	.166	-.007	-1.227	.484	-.052	.774	.344	.051
N = 1041	s	.094	.363	.103	.104	.741	.151	.095	.568	.121	.033
TOTALS (3 Altitudes)	$\overline{m}$	-.0705	-.2359	.2165	-.0545	- .948	.553	-.0943	.777	.392	.0526
N = 2811	s	.1038	.4533	.1223	.1128	.7131	.1882	.1048	.5482	.1515	.0336
DISPLAY 2											
Altitude No. 1 (20,000)	$\overline{m}$	.002	-.111	.197	-.013	-1.09	.575	.008	.865	.453	.049
N = 710	s	.089	.526	.130	.093	.683	.584	.093	.569	.208	.044
Altitude No. 2 (10,000)	$\overline{m}$	-.0908	-.277	.269	.014	-1.143	.577	-.064	.594	.357	.073
N = 887	s	.2123	.676	.755	.352	.772	.455	.090	.703	.184	.151
Altitude No. 3 (5,000)	$\overline{m}$	.014	-.177	.148	.002	-1.145	.464	.018	.844	.380	.044
N = 891	s	.075	.526	.126	.080	1.057	.197	.085	.508	.171	.057
TOTALS (3 Altitudes)	$\overline{m}$	-.027	-.104	.203	.003	-1.129	.538	-.014	.761	.434	.062
N = 2488	s	.128	.565	.173	.181	.849	.306	.099	.595	.206	.096

N = number of observations or data points
$\overline{m}$ = mean value
s = estimated standard deviation

TABLE 2. SUMMARY CALCULATIONS BY RANGE

		VARIABLES									
					Trailing Edge			Leading Edge			
DISPLAY 1		1	2	3	4	5	6	7	8	9	10
0 - 18.5 miles	$\overline{m}$	−0.042	−0.405	0.179	−0.017	−1.959	0.426	−0.073	1.197	0.307	0.055
(N = 749)	s	.094	1.034	.102	.103	.850	1.019	.097	.763	.108	.033
18.5 - 29.5 miles	$\overline{m}$	−0.056	−0.250	0.196	−0.031	−1.275	0.545	− .088	−0.800	0.390	0.053
(N = 847)	s	.090	.332	.114	.092	.405	.146	.094	.365	.120	.032
29.5 -	$\overline{m}$	−0.094	−0.143	0.241	−0.083	−0.812	0.567	−0.113	0.543	0.406	0.054
(N = 1353)	s	.091	.223	.121	.099	.307	.211	.110	.299	.178	.035
DISPLAY 2											
0 -18.5 miles	$\overline{m}$	−0.001	− .246	0.186	−0.011	−1.347	0.350	0.004	0.908	0.299	0.034
(N = 882)	s	.073	.812	.096	.076	.934	.146	.076	.861	.114	.022
18.5 - 38.5 miles	$\overline{m}$	−0.038	− .129	0.196	−0.061	−1.101	0.566	0.007	0.811	0.418	0.073
(N = 937)	s	.142	.342	.171	.225	.395	.296	.071	.383	.131	.101
29.5 -	$\overline{m}$	−0.022	−1.149	0.234	−0.030	−0.789	0.628	−0.024	0.546	0.475	0.049
(N = 1379)	s	0.104	.254	.152	.108	.377	.337	.108	.524	.139	.052

N = number of observations or data points
$\overline{m}$ = mean value
s = estimated standard deviation

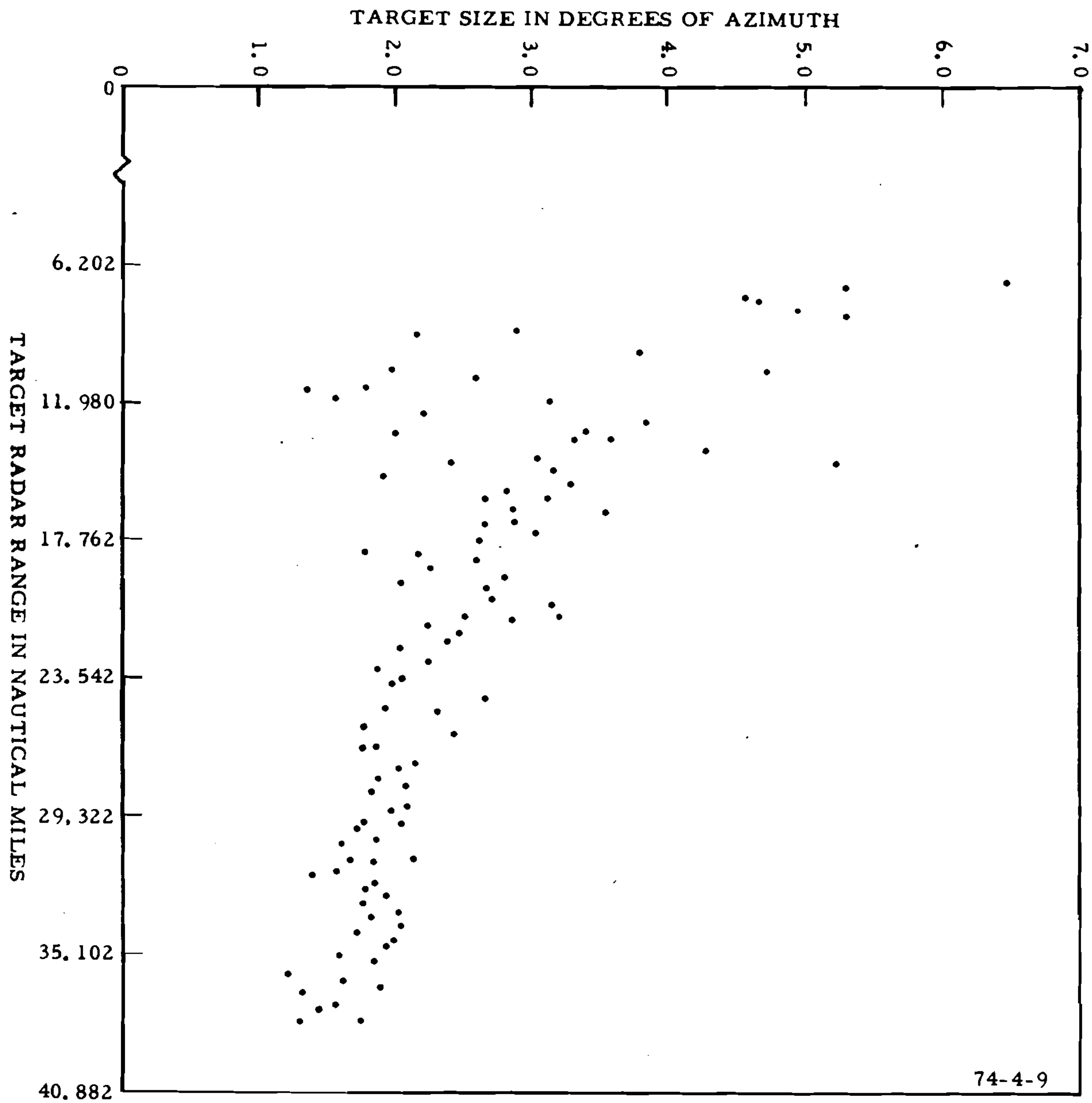

FIGURE 8. AZIMUTH SIZE OF TARGET (DEGREES): ALTITUDE 20,000

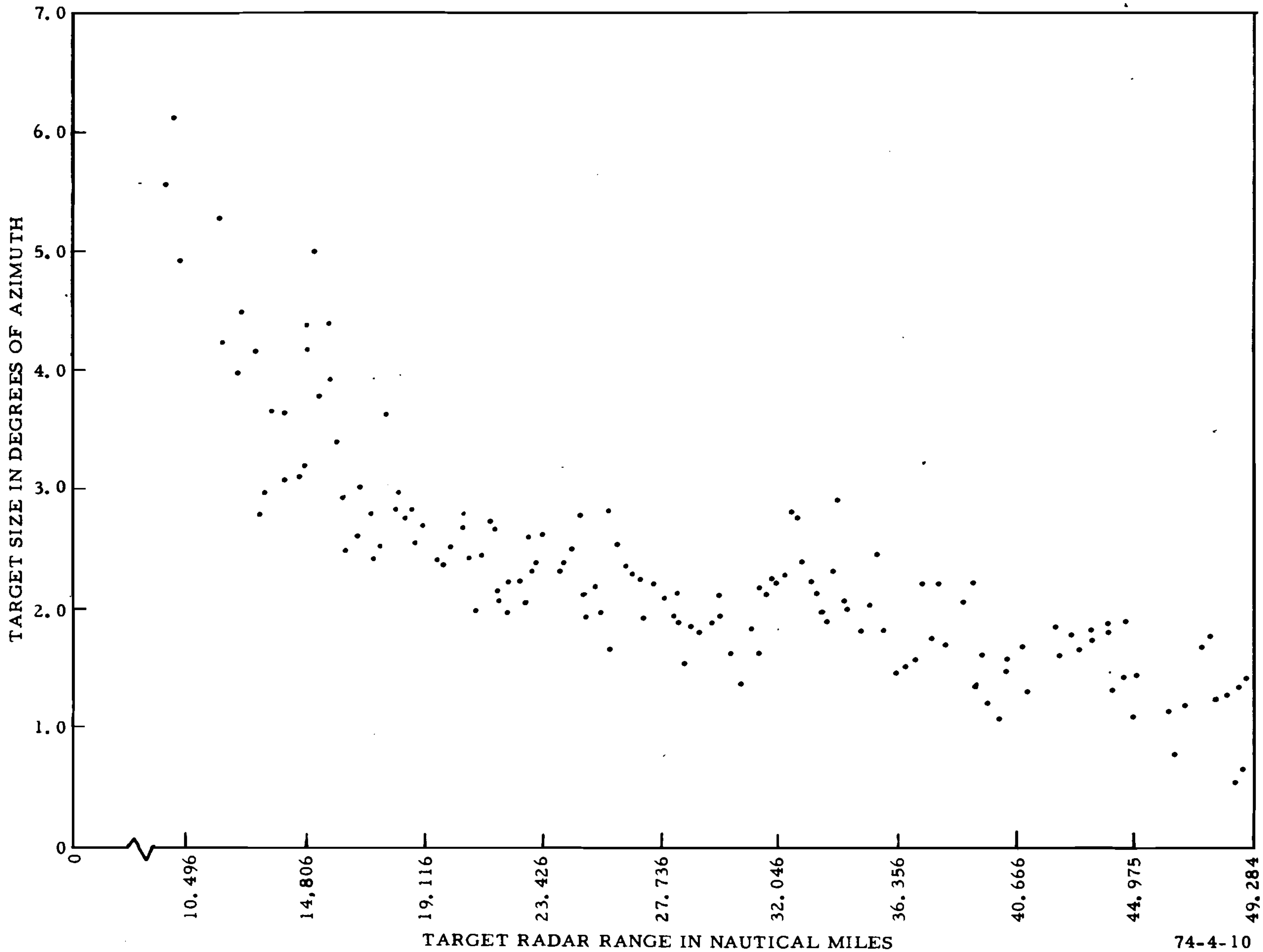

FIGURE 9. AZIMUTH SIZE OF TARGET (DEGREES): ALTITUDE 10,000

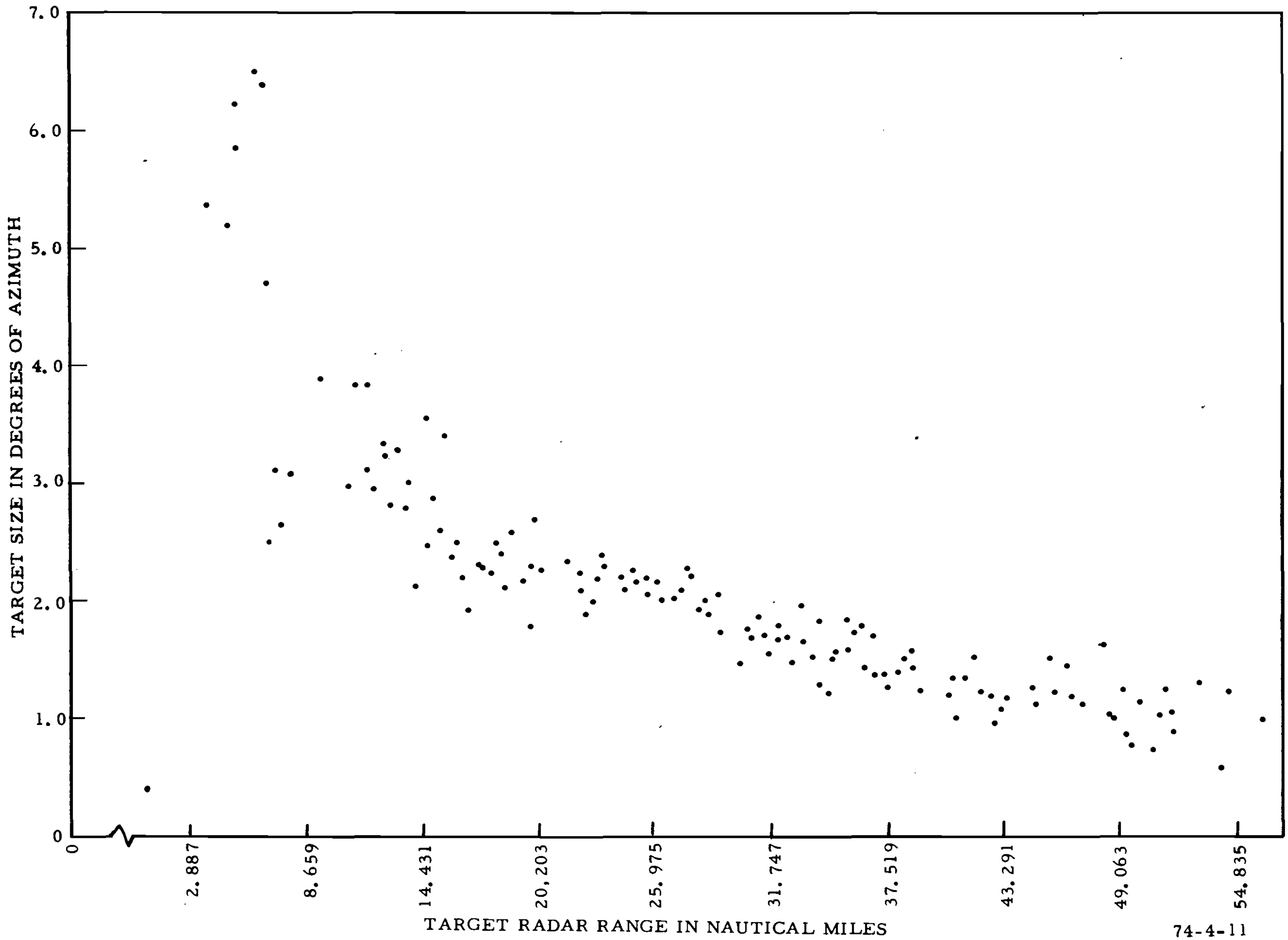

FIGURE 10. AZIMUTH SIZE OF TARGET (DEGREES): ALTITUDE 5,000

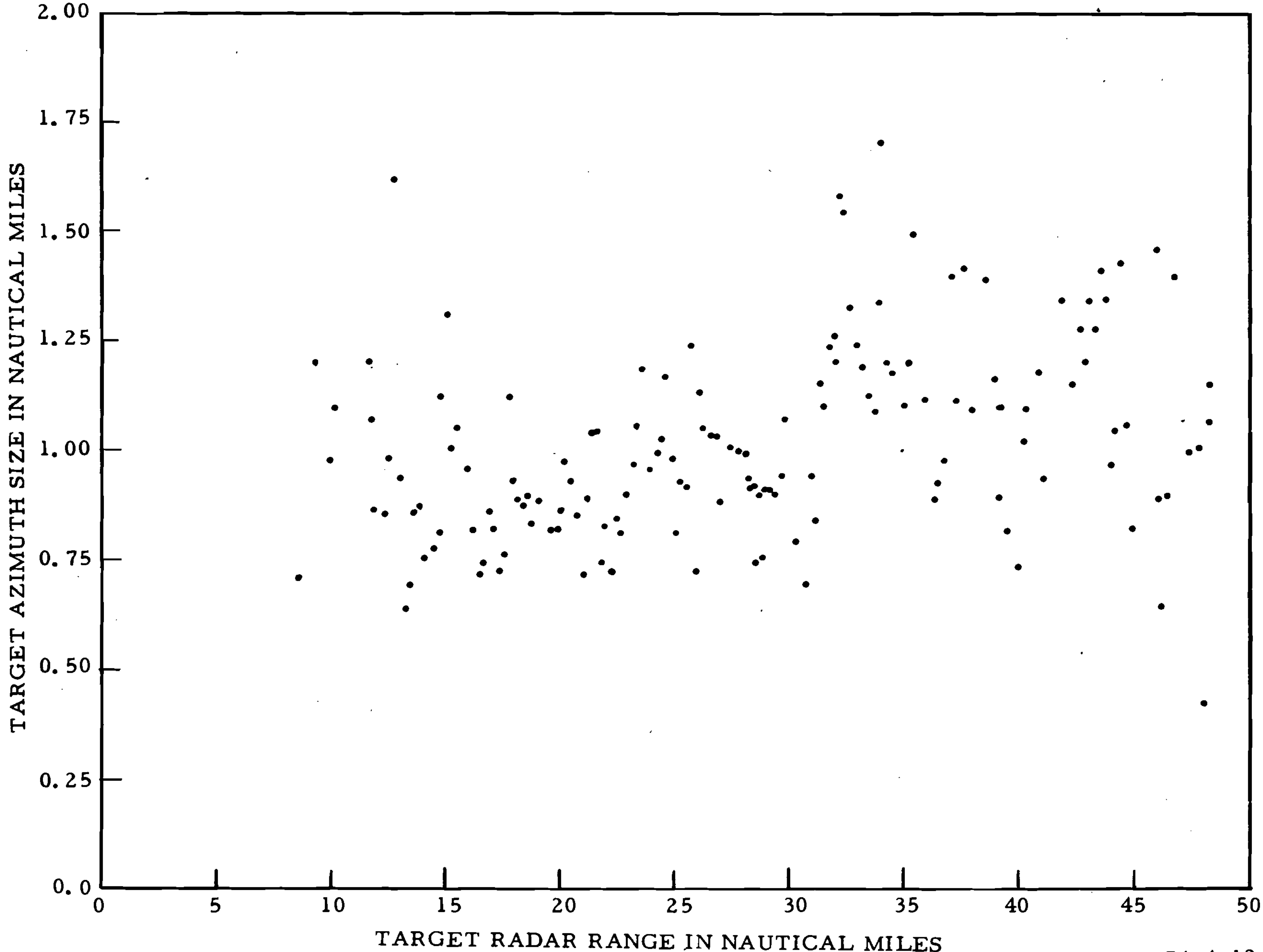

FIGURE 11. AZIMUTH SIZE OF TARGET (NAUTICAL MILES): ALTITUDE 10,000

The data from tables 1 and 2 indicate that the center of the DAIR symbol was almost always closer to the radar leading edge of the primary target (variables Nos. 8 and 9) than to the trailing edge (variables Nos. 5 and 6).

A statistical test of the frequency with which the DAIR symbol was closer to the leading edge demonstrates that it was significant at greater than the .001 level.

The question concerning the use of the DAIR symbol is, what is the likelihood or probability that the DAIR symbol would not be superimposed on the top of the associated primary radar video target? The answer to this question, to some degree, determines whether the DAIR-processed target symbol alone (without backup by other modes of radar target presentation) may be used for the control of aircraft in an air traffic control environment. This question cannot be answered directly. The data in figures 8 through 11 indicate a considerable amount of variability in the primary target size from scan to scan. Thus a measurement scheme to determine the frequency with which the DAIR symbol failed to coincide with the primary target on a scan-by-scan basis would have been necessary. From the data measurements that were made, it was possible to determine the frequency with which the azimuth of the DAIR symbol center fell outside the azimuth coordinates of either the radar leading or trailing edge of the primary targets. One percent of the time the DAIR symbol center fell outside of the boundary defined by the azimuth of the trailing edge, and 4.5 percent of the time the DAIR symbol center fell outside of the boundary defined by the azimuth of the leading edge.

To further analyze this problem, the size of the primary radar video target on the PPI was measured for both the width (azimuth) and depth (range). Also the position of the DAIR symbol center relative to the center of the primary target was measured.

Figure 12 depicts the GENERAL relationship of this data. The larger set of three concentric ellipses indicates the size of the primary radar video target for the conditions measured under this program. The smaller set of three concentric ellipses indicates the most probable position of the DAIR symbol center relative to the center of the primary radar target; and the location of the center of the primary target in this figure is the intersection of the coordinate lines at coordinates 0,0. This is, of course, the center of the larger set of ellipses, despite the optical illusion resultant from the offset bias of the smaller set of ellipses.

For both sets of ellipses, the innermost rings of each set are the respective 50 percent confidence ellipses, the middle rings are the 95 percent confidence ellipses, and the outermost rings (of each set) are the 99 percent confidence ellipses.

The size of the primary radar video target is indicated in the larger set of three concentric ellipses as follows: (1) the innermost ellipse represents the average size, or 50th percentile; (2) the middle ellipse represents

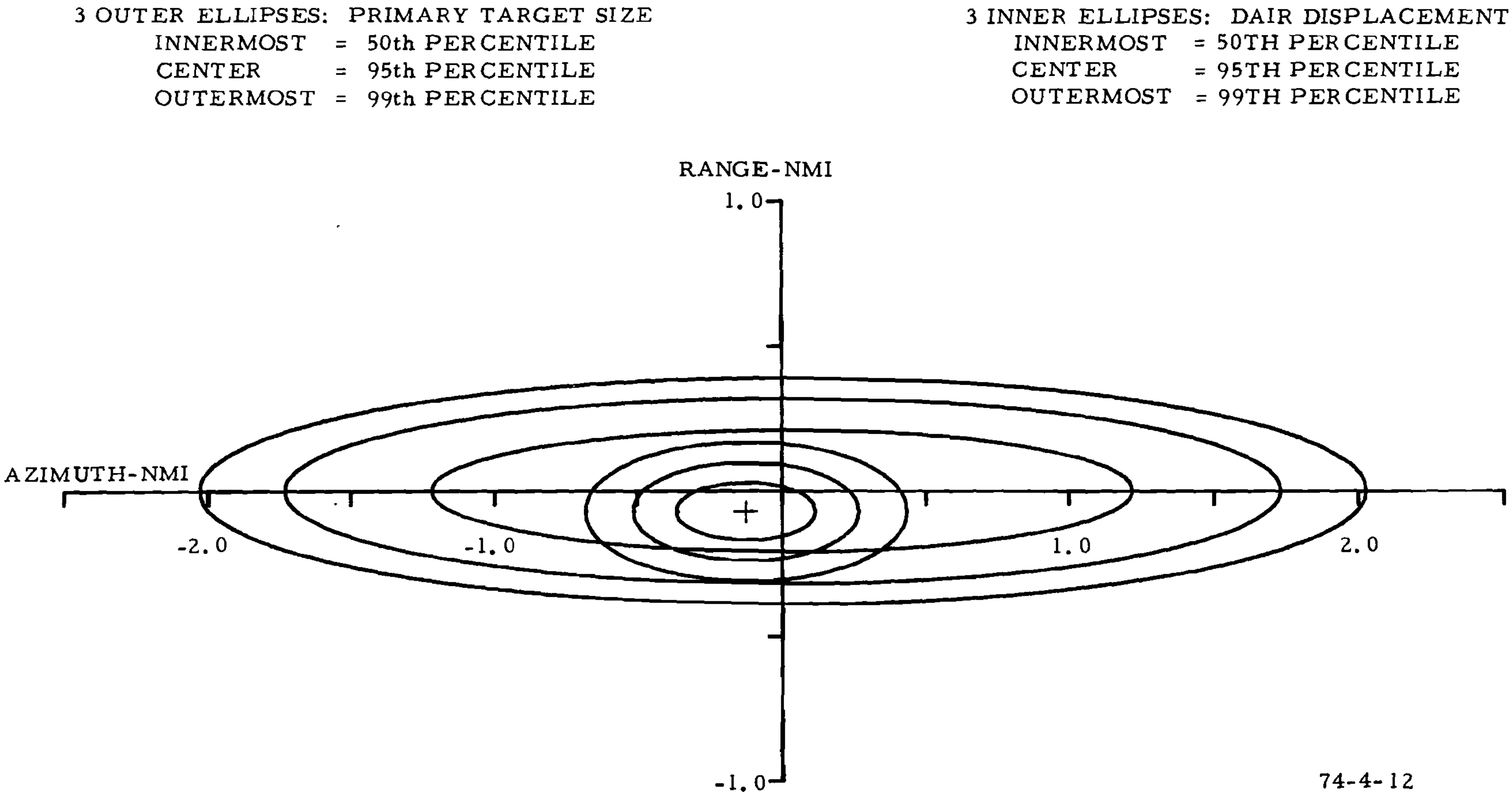

FIGURE 12. DISPLACEMENT OF DAIR CENTER MARK RELATIVE TO PRIMARY RADAR TARGET SIZE

that area which encompasses 95 percent of all primary targets, or the 95th percentile; and (3) the outermost ellipse represents the 99th percentile; or area within which 99 percent of primary target sizes were encompassed.

The position of the DAIR symbol center relative to the center of the primary target is indicated in the smaller set of three concentric ellipses as follows: (1) the innermost ellipse represents the 50th percentile, the area within which 50 percent of the time the DAIR symbol center fell; (2) the middle ellipse of this set represents the 95th percentile; and (3) the third ellipse of this set encompasses the area within which the DAIR symbol center fell 99 percent of the time, the 99th percentile.

The data indicates that the dimensions of the innermost ellipse (the 50th percentile ellipse of the smaller set) were approximately .478 nautical mile in azimuth and .208 nautical mile in range. The DAIR target symbol center fell within such an ellipse 50 percent of the time. Further, the coordinate location of this series of ellipses, as previously stated, is offset from the center of the primary radar target (coordinates 0,0) in a direction toward the leading edge of the primary target (to the left in figure 12), and slightly offset in a direction toward the radar antenna.

The reader should be cautious about any rigorous interpretation of figure 12 because the data are a statistical abstraction of the so-called typical target sizes and relative positions. At any one time, or scan of the antenna, the DAIR symbol might or might not be encompassed by any one of these ellipses, dependent upon the correlation of the scan-by-scan displacement. Thus, the real probability of the DAIR symbol center being within the area of the primary radar video target is not any simple arithmetic combination of the two probabilities, as indicated in figure 12, but probably some nonlinear function dependent upon the statistical correlation of the two targets.

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